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Abstract: In this paper, we present the design and the implementation of a contextual and multimodal information diffusion system for museums. We propose a proactive service (1) with the ability to sense the profile of nearby visitors, using RFID and WLAN connectivity, (2) that adapts the information content to the target user, and finally (3) that distributes automatically the information to several devices, collective devices like large wall panels disseminated in museum or directly to digital guide carried by visitors.

Key-words: Pervasive computing, context-awareness, location service, RFID, WLAN

Mise en œuvre d'un service de diffusion d'information contextuel utilisant un mécanisme de localisation à base d'étiquettes électroniques

Résumé : *Dans ce rapport, nous présentons la mise en œuvre d'un service contextuel et multimodal, permettant la diffusion d'information dans les musées. Ce service proactif (1) capture des profils de visiteurs se trouvant dans le même voisinage physique, (2) réalise l'adaptation de l'information en fonction de l'utilisateur visé, et enfin (3) distribue automatiquement les informations vers différents équipements, des guides électroniques utilisés par les visiteurs jusqu'aux écrans d'affichage disséminés dans le musée.*

Mots clés : *Informatique diffuse, sensibilité au contexte, service de localisation, étiquette électronique, réseaux locaux sans fil*

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1 Introduction

Providing pertinent and accessible information to people in a museum has always been a challenge. Broad availability of fast mobile Internet through WLAN and cellular networks enables unlimited access to cultural digital content. The amount of cultural information targeting mobile users is rapidly increasing and a huge number of web repositories for tens of museums is now available. Therefore the main problem for a visitor is not any more to find information, but to retrieve pertinent information depending on the context of the visit (duration of the visit, user's location, user's interest etc.).

The SmartMuseum[1] European project aims to address efficient on-site cultural heritage content access by monitoring user's activities. Mobile device is one of the two main subsystems in the SmartMuseum architecture, the other one is the profile matching / recommendation server. The latter is able to assist the user to find contents that are likely of interest for the user [1]. It reduces the need of interaction with the device. That is particularly important in ubiquitous scenarios, where the usability of the mobile devices often limits the user's willingness to perform complicated search queries.

The mobile device is the main interaction point to the system for the visitor. In a SmartMuseum scenario, a visitor explicitly requests information from an item among a list proposed by the recommender system, or read a RFID, associated with the local area or an object of this area. In that case, a URI stored into the RFID, allows to retrieve information. These interactions can be seen as "pull" type. The visitor carries a PDA, offering him access to web-type information system in a contextual manner: requests include context descriptors such as current position or user profile that can influence the available information or its presentation. This approach is presented in [2].

A recommender system combined with an explicit selection of the information by the visitor (touching an object in a recommendation list and/or reading a RFID a in given area) offers a good solution but also has limitation. First it assumes that the selection interface can be easily used by the visitor, which may not always the case. For example, the user with visual disability will not be aware of the availability of a short-lifetime information (announcement of the beginning of a conference in the museum). Second this approach is limited to provide information proposed by the recommender system and requested by visitors, not unsolicited information.

Our idea is to provide a proactive service that senses the environment and spontaneously adapts its behavior to the local context. Typical sensing involves determining the profiles of near by visitors, allowing the dynamic computation of group profiles and enabling global adaptation of the environment to the context. For example, if a room in the museum uses vocal explanations or shows short documentation movies, environment sensing enables automatic selection of the dominant language (and appropriate selection of subtitles in the case of a movie) accordingly to the current visitors in the area.

The objective here is to offer the possibility to mobile device to receive automatically contextual information. A proactive service senses the environment and spontaneously adapts its behavior to the local context. The interactions between the mobile device and the SmartMuseum server can be seen as "push" type. The notion of "context" considered here refers to a description of a physical situation in the museum; a physical situation may be described by low descriptors such as raw sensor values (GPS position, RFID, etc.), but these one are usually not directly relevant for an application. Here we propose to use RFID disseminated in the museum in combination with WLAN connectivity for designing a location service in the museum. And context-awareness requires higher level description that can be used easily by service. For example, an application shouldn't have to do only position computation if the goal is to determine what is the language spoken by nearby people. So we use existing parameters (mainly the spoken language) extracted from the existing user's profile used by the initial *pull mode*. Of course, monitoring the environment to identify people and using user's profile parameters raises a strong privacy concern. This problem is addressed in this paper.

The purpose of this paper is to present our results with the design and the implementation of such a service. This work is an extension of the initial SmartMuseum architecture [2], and of an ambient service we initially designed for transportation systems [4]. The rest of the paper is organized as follows: in the second section we present the principle of the diffusion service for museum. Then the third section describes the system architecture and its implementation. The underlying location service is presented in the fourth section. Finally in the last section, we present related work and the conclusion.

2 Motivation for a diffusion service in a museum

In a museum, visitors may speak different languages, have a disability, and can be interested by different information. A classical strategy is to deliver *variants* of the same information, for example versions of different languages. The problem with this approach is that all variants cannot be delivered to all mobile devices, (1) due to the limited size of the screen of a mobile device and (2) because it tends to flood underlying wireless communication infrastructure.

Our objective is to design a context-sensing information diffusion system to detect and identify group of users (co-located in a given area of the museum), and to provide them with unsolicited messages like "conference invitation at 1pm, room leonardo", with a multi-language support, and multi-modal support. For example, Text To Speech (TTS) functionality will be automatically activated for people with visual disability. Two aspects must be addressed for implementing such a service.

[1] www.smartmuseum.eu

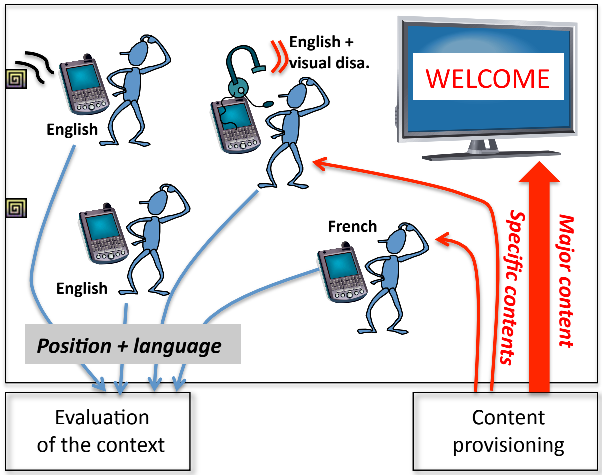

Figure 1: Overview of the diffusion system

First the service requires determining *visitor's context in a given spatial area of the museum.* For that, two kinds of information are required: visitor's localization and personal parameters like "spoken language" and "ability to see". Localization can be accessed using RFID reading, combined with WLAN connectivity. Personal parameters can be extracted directly from SmartMuseum profile stored in mobile device. Of course collecting these data (localization and parameters of the profile) in museum environment is a privacy concern, as it potentially enables visitor tracking when associated with SmartMuseum user's account. So we only use "anonymous attributes" of the user's profile such as "language spoken", and information sent by mobile device application is not associated with SmartMuseum user's account.

Second a *provisioning strategy* is decided to target visitors in an efficient way. By efficient, we mean allocating the collective resources to larger groups (the "major" spoken language), and using mobile device for smaller groups. For that, we use the majority rule: the collective devices (or example large wall panels) are allocated to display message in "major" language, while messages in "minor" languages and messages "compliant with Text To Speech engine" for users with visual disability, are forwarded to mobile devices.

These both aspects are summarized in Figure 1.

3 Presentation of the system architecture

Context sensing generally involves two types of operation:

- Getting on context attribute, which is basically a "read" operation on context-derived data.
- Triggering an operation when a context-specific condition is met.

A simple and efficient abstraction that provides both functionalities is a tuple space model, such as SPREAD [3]. In the following, we describe briefly how the tuple space model can be used as a context-aware abstraction.

3.1 Tuple space as a context-aware abstraction

Tuple spaces use a shared data structure for enabling dynamic cooperation between applications. Data are structures made of sequences of basic data types, such as $<"french", 1>$ which describes a visitor who speaks French, the last field is set to 1 to indicate that the Text To Speech (TTS) functionality must be used. In the case of pervasive computing, the tuple space is typically shared between objects in the same physical context, allowing implicit spatial addressing of data provided in the same "memory bubble" (*i.e* in our approach, the bubble corresponds to WLAN communication range). For example, collecting all the French users in the room could be expressed by a request pattern like $read <"french", ?id>$. Such a request can wait until a matching tuple is found (which means a French user enters the room in the museum), providing a way to control the flow of a program according to environment events.

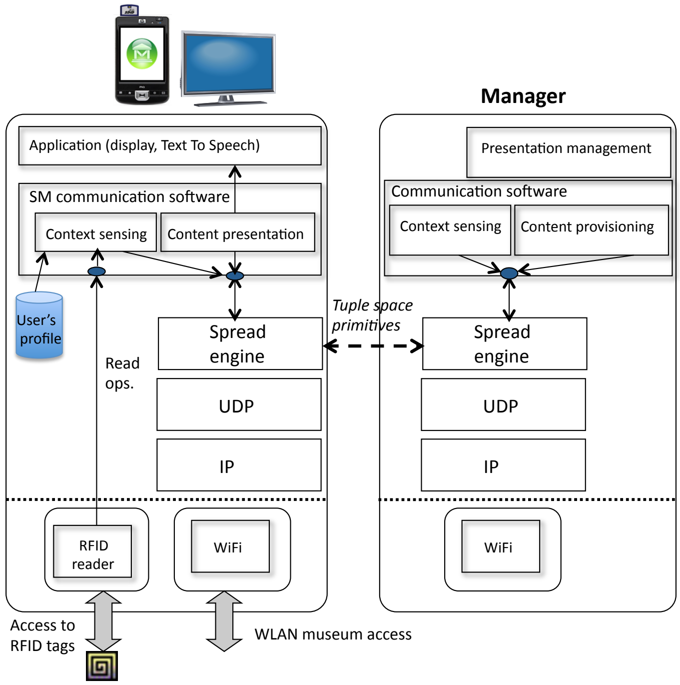

Figure 2: System architecture

So we propose to use this tuple space abstraction to implement a push service on mobile devices. The targeted service is insured by (1) an application running on the mobile devices carried by the visitor and on the collective devices, and (2) a "service Manager" possibly located in the museum, or directly integrated in SmartMuseum server. These components are presented in Figure 2.

3.2 Context sensing and location service

The goal of profile sensing modules (on mobile device and Manager) is to determine the visitor's context in a given spatial area of the museum. For that, two kind of information are required: visitor's localization and two personal parameters extracted from local user's profile ("language" and "ability to see"). When using SmartMuseum application, a visitor reads an RFID storing an object URI (for example **urn:imss:instrument:4040**). With this information, mobile device retrieves automatically the main object information page, associated with (1) the object room location, (2) content URLs provided by the museum and (3) external content URLs (for example wikipedia links related to the museum object).

We made the assumption that if the Manager knows the tag read by a visitor, it could localize him in the museum. So when a device reads a RFID, it publishes automatically the associated room location using a SPREAD function. Then if this device can be seen by the Manager (using *capture* function), the latter can deduce that (1) the mobile device is connected to WiFi network of museum and (2) it is near the tag. Using combined RFID reading / WLAN connectivity, the Manager can obtain a good approximation of user's localization. Finally, a tuple is published by the mobile device just after RFID reading using the call $Out < room, age, language, TTS, Hash@MAC >$ where

- age is a counter indicating if the user's location is still valid or not (see more explanations below).
- TTS is a boolean value defining if the Text To Speech functionality must be used.
- $Hash@MAC$ is a hashed value of WiFi physical address of the device. Hash function is used to guarantee user's anonymity (login is not used), and is used by the Manager for identifying mobile device.

Of course, when no new RFID is read, localization information can become obsolete. In order to characterize the validity of the information of localization, we introduce a counter *date* into the tuple published by the device. This counter is initialized to 0 when a RFID is read, and maintained at this value as long as the visitor browses among information (URLs and external links) related to the RFID. On the other hand if no activity is detected in the terminal, the counter is incremented every 30 seconds, and the terminal is considered as "non localized" when *date* is equal to 3. This principle is presented in Figure 3.

On server side, the Manager retrieves all "localization tuples" published by mobile devices using *capture* function.

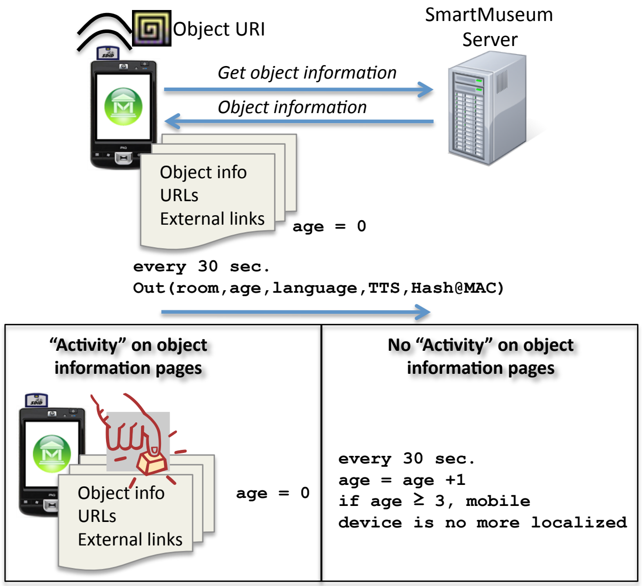

Figure 3: Location mechanism

3.3 Content provisioning

According to information provided by context sensing module, content provisioning module is able to identify a specific group of visitors in the museum (for example people in a room), and to calculate a "major group" and a set of "minor groups". When a message must be sent to this group, content provisioning module publishes a tuple in the museum : $Out < room, validity, ID\_msg, message, majority, TTS >$, where

- $room$ is the room number. This parameter is equal to -1 if the message must be sent to all visitors in the museum.
- $validity$ corresponds to the time of validity of $message$ sent in the tuple.
- ID_msg is used to identify the message sent by the Manager. Information is transmitted over an unreliable channel (802.11/IP/UDP). So it is sent several times by the Manager as $message$ remains valid. In case of multiple reception, the terminal takes into account only once a given identifier.
- $majority$ is a boolean indicating whether the language used in the tuple is dominant. If the majority language is the language of the visitor, the contents of the message is not displayed by the terminal, a simple sound signal returns the visitor towards the collective screen.
- TTS is a boolean indicating whether the message sent in the tuple is the version to be played by the Text To Speech engine implemented in the terminal.

3.4 Implementation

Mobile device. The mobile application (context sensing, tuple engine, GUI) has been implemented on a PDA HP Ipaq 214, running under Windows Mobile. TTS (Text To Speech) functionality is based on the integration of an external Text To Speech engine [5].

RFID reading. For SmartMuseum experimentations, the objects have been equipped with 13,56MHz (ISO14443A) RFID tags used for content triggering and user's positioning. At now PDA and Smartphones do not support natively tag reading. So we used an SDIO HF RFID reader (SDID 1020 from Wireless Dynamics). But in a near future this functionality will be largely implemented on several mobile phones using NFC standard. So we stored information on tag so that SmartMuseum RFID can be also read (without any specific application) by NFC phone. For that goal memory of tags contains (see Figure 4) "MIFARE Application Directory" (MAD), an index of all applications stored in the tag, "Application 1" using NFC Smart Poster format.

The Smart Poster content is used to display on the PDA screen information corresponding to the museum object. Two areas are used, just after the application header (see Figure 4): (1) the *header* stores the type of application and the payload size, (2) the *Title record* contains generally a common name for the object or service referenced by the URI (it can be the bookmark name if a URL is provided in the following record; in our application, it is used as object URI), and (3) the *URI*

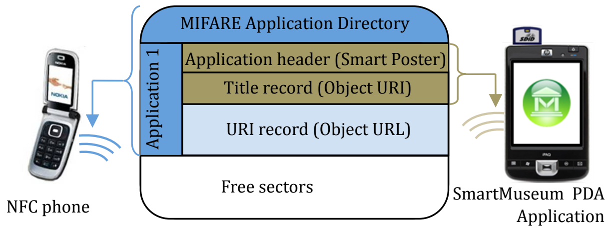

Figure 4: RFID tag format

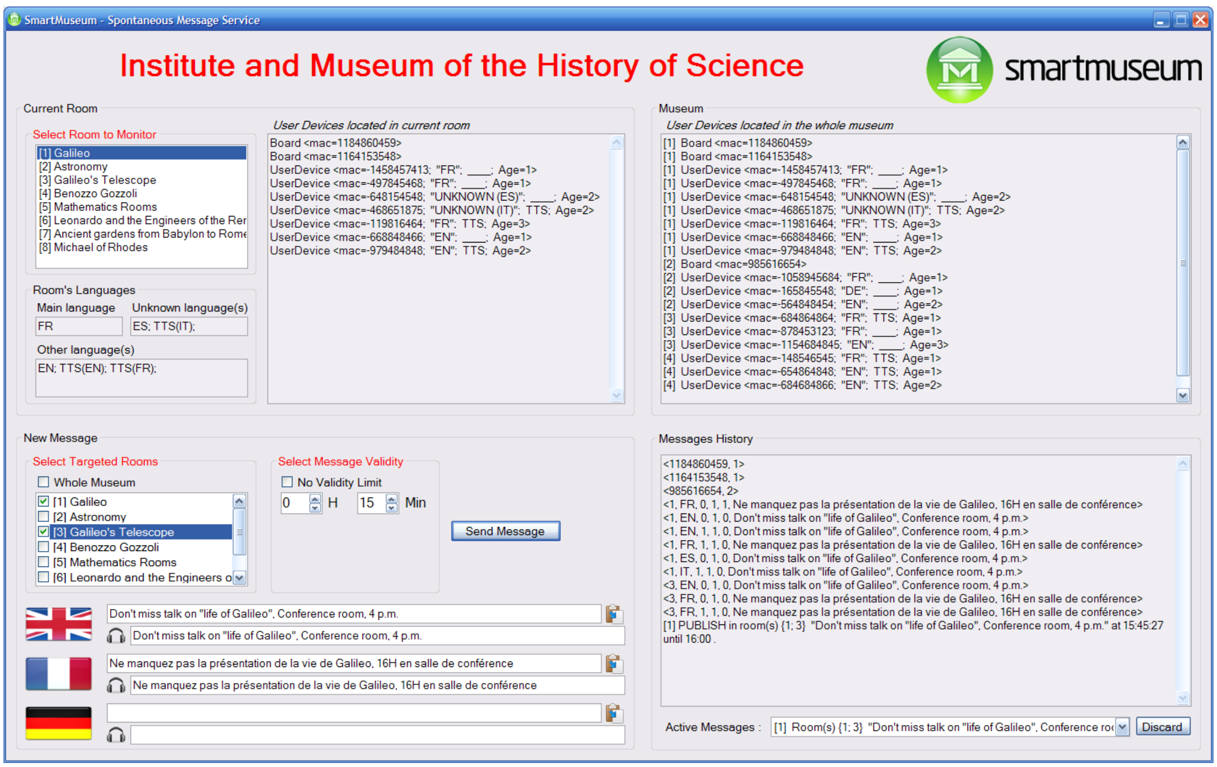

Figure 5: Management of SPREAD messages on Manager

record provides object URL, it is used by NFC phones to store and to display automatically a webpage on the NFC phone. The use of two distinct fields for PDA and NFC phones allows to take benefit from both device types. Our tests showed that this "SmartMuseum tag format" allows a NFC phone to read object tag and to automatically retrieve information on SmartMuseum server.

Manager. The server (location service and content provisioning) is a .NET application allowing museum's administrator to monitor "major" and "minor" user's groups in the museum and to manage through a simple graphical user interface all variants of SPREAD messages (see Figure 5).

3.5 Analysis of our results

Our architecture is able to provide pertinent and accessible information for visitors in a museum. An other important feature of our system is that context sensing is based on a very simple location service. In many museums, RFIDs are already used for object referencing. Our system can be easily deployed, just by using existing tags and WLAN communications. The main weakness of our approach is that localization parameter calculated by the location service is false if a visitor does not read any RFID. In the next section, we propose a simple solution to improve visitor's localization: our approach is to allow mobile device to detect a "neighbor terminal" that has recently read a RFID. For evaluating this proximity, we use the similarity of radio conditions: two terminals are considered as neighbors if (1) the measured radio signal strengths are close to each other and (2) the both devices are attached to the same WiFi Access Points.

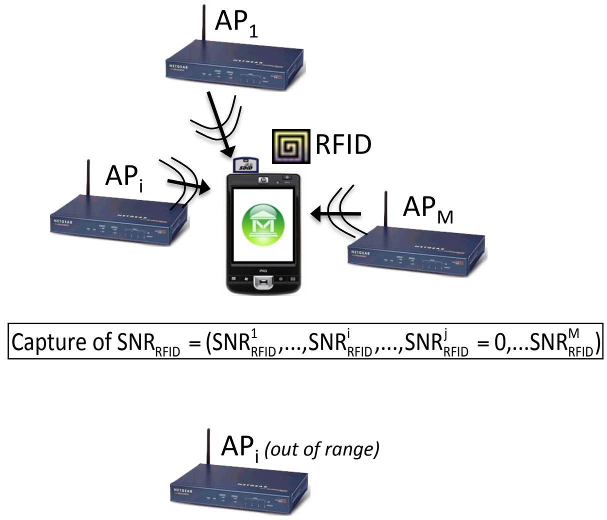

Figure 6: Capture of the radio conditions

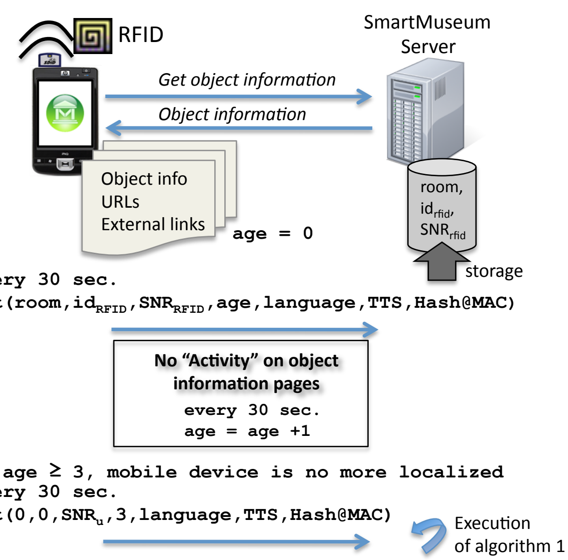

Figure 7: Improved location mechanism

4 Extension of the location service

As illustrated in Figure 3, a visitor is localized whenever he reads a RFID and he uses related data on its PDA. But afterwards if no RFID is read in the museum, the visitor is not taken into account when "major" and "minor" groups are calculated. We propose two new steps in order to improve existing location service:

1. Whenever a user reads a RFID, the PDA evaluates its radio conditions, and sends them to the server. These data are kept in the server until user's localization becomes too old (e.g. $age \geq 3$).

2. When a user is no more localized, PDA evaluates its radio conditions, and sends them to the server. Then the server compares these values to other local values associated with nodes that are still localized.

Two parameters have been considered to evaluate radio conditions: RSSI (Received Signal Strengh Indication) and SNR (Signal to Noice Ratio). To the common knowledge, both parameters are equally suitable for developing WLAN positioning service [10]. We chose finally the SNR, because it can be easily measured on many WLAN interfaces.

4.1 Principle

Whenever a user reads a $RFID$ tag, it captures not only information from the $RFID$ tag, but also the SNR value of each WLAN Access Points (AP) in its communication range. Finally, the radio conditions are represented by the set $SNR_{RFID} = \{SNR^1_{RFID}, SNR^2_{RFID}, ..., SNR^M_{RFID}\}$, where M is the number of AP deployed in the museum. Of course when an AP is out of range, the corresponding SNR value is set to 0 (see Figure 6).

After that, the PDA publishes a SPREAD message to the server as in Figure 7. The initial message defined in Figure 3 is extended with two new parameters: id_{RFID} and SNR_{RFID}. The triplet $\{room, id_{RFID}, SNR_{RFID}\}$ is stored on the server while user's localization remains valid (e.g. $age < 3$, see Figure 7).

When a user is no more localized, it sends its radio conditions $SNR_U = \{SNR^1_U, SNR^2_U, ..., SNR^M_U\}$. After receiving the published SPREAD message, the server performs algorithm 1 based on location information stored in its database. This algorithm calculates the best position where the user is likely to be. This step is described in Figure 7.

The server performs the location algorithm by combining user's information (SNR_U) and valid positions in its database (set of SNR_{RFID}). It collects N valid positions whose values SNR_{RFIDi} are close to SNR_U with an acceptable error equal to δ_{SNR} (e.g. $\forall k, 1 \leq k \leq M, SNR^k_{RFID_i} = |SNR^k_U \pm \delta_{SNR}|$). In our study, $\delta_{SNR} = 1dB$. Then two methods can be used to estimate user's location:

1. Among the N valid positions, if there are n positions that are in the same room $Room$ and if n is greater than a half of N, then the server might conclude that the user is in the room $Room$.

2. Otherwise, the server will determine the user's position that has a minimal standard deviation σ_i (i= 1,2,...,N). The latter is calculated using the formula: $\sigma_i = \sqrt{\frac{1}{M} \cdot \sum_{m=1}^{M}(SNR^m_i - SNR^m_U)^2}$, M is the number of access points in the museum. Finally the user has a second possible position with a standard deviation little greater than the previous one.

If the server does not yet find a position, it announces that the location is unknown. All these steps are presented in the following algorithm:

Algorithm 1 Calculation of a user's location

Require: Server has received SNR_U
Require: M Access Points are deployed
  var RFIDlist : set of RFID
  $RFIDlist \leftarrow \emptyset$
  for all $RFID_i$ such that $SNR_{RFID_i} \in (SNR_U \pm \delta_{SNR})$ **do**
    $RFIDlist = RFIDlist \cup \{RFID_i\}$
  end for
  if $card(RFIDlist > 0)$ **then**
    if $((\exists\ n\ RFID_i \in Room)$ && $(n > card(RFIDlist)/2))$ **then**
      return *Room*
    else
      for all i such that $RFID_i \in RFIDlist$ **do**
        $\sigma_K = min(\sqrt{\frac{1}{M} \cdot \sum_{m=1}^{M}(SNR^m_{RFID_i} - SNR^m_U)^2})$
      end for
      return *Room* associated with $RFID_K$
    end if
  else
    return *Unknown Location*
  end if

4.2 Simulation and evaluation

Our goal is to study the efficiency of our location algorithm. For that, we proceed by simulating the museum environment. We use the OPNET Academic edition simulator. The features of the topology configuration is as following:

1. The wireless infrastructure spans an area of 100 x 100 meters.

2. There are one server and three APs.

3. WLAN technology is Wifi IEEE 802.11g [16].

4. Simulation time is 30 min.

Date Rate (Mbps)	54
Physical characteristics	Extended Rate PHY (802.11g)
Channel	1 ; 6 ; 11
Transmit Power (W)	0.2 (AP) - 0.005 (node)
Packet Reception-Power Threshold (dBm)	-95

Table 1: Parameters of the WLAN APs and nodes

The configurations of the WLAN nodes and APs are described in Table 1.

In the area of museum, user's movements are simulated using two models: (1) a mobility model with predefined trajectories and (2) the Random Way Point (RWP) model.

For the mobility model with predefined trajectories, we determine the paths whose stops are specific points that correspond to the positions of RFID tags. The nodes of this model move with velocity $v = 0.5m/s$ and take a pause of 10 seconds at each stop. We select 100 points in the simulation area corresponding to the positions of RFID tags. At each stop, a node using this model of mobility captures SNR values for each AP. An example of data captures on these 100 positions is given by Figure 8.

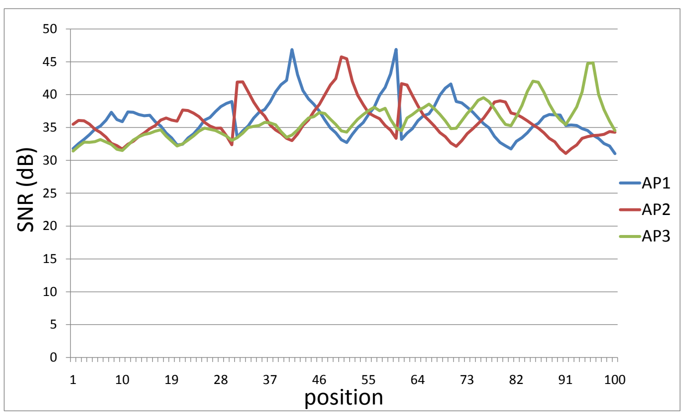

Figure 8: SNR values for a node with predefined trajectory

With the RWP model, mobile nodes are initially uniformly distributed in the range of simulation. Then, nodes move in a direction randomly chosen with a constant speed $v = 0.5m/s$. Upon arrival, the mobile node pauses for 60 seconds before making another move. We use this second model of mobility to have a realistic simulation environment. Indeed, the radio conditions (SNR or RSSI) of a node can vary in the presence of other nodes in the physical neighborhood. Thus nodes using RWP model are injected into simulations, in order to test the location algorithm under realistic radio conditions. For example, Figure 9 presents SNR values of two close nodes for a given AP. The two curves are quite similar, the difference does not exceed a few dB. These small variations reflect changes in the vicinity, they are induced by other mobile nodes.

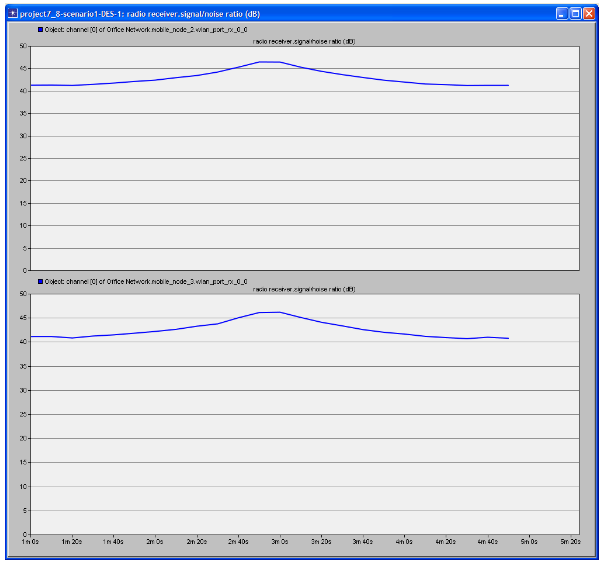

Figure 9: SNR values of two neighbor nodes

During simulations, we varied two parameters: the number of nodes, and the duration during which an information of localization (parameters SNR_{RFID}) remains valid. In the solution presented in 4.1, this duration was fixed at 90 seconds ($age < 3$). It seemed interesting to increase this duration, in order to evaluate the impact on the results of our algorithm.

Through simulations, we generated SNR logs, to which we applied the location algorithm. Figure 10 presents the results for two numbers of visitors (72 and 102). The x-axis represents the validity of information of localization SNR_{RFID} ($30sec$, $60sec$, ...). The y-axis indicates the percentage of correct localizations.

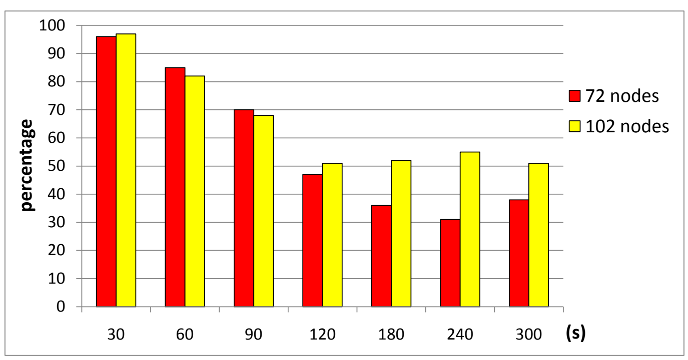

Figure 10: Simulation results

Below threshold of validity (90 seconds), the algorithm gives good results: at least 70% of calculated positions are exact. One can also note that the number of users does not have impact on quality of the results. The chosen period of validity is suited to the targeted application. These results are degraded beyond 90 seconds, the percentage of good evaluations do not exceed 50%, and the lower the density of the nodes is, the more the effectiveness of the algorithm decreases.

5 Related work

We propose a simple architecture for providing pertinent and accessible information to visitors in a museum. Defining smarter ways to deliver information in cultural areas is not new. Since the concepts of context-awareness was introduced by Weiser in [6], many prototypes of ambient information systems appeared such [7], [8] and [9]. In these systems, the user carries a mobile device that is the main interface with the information system. Considering existing systems, the main feature of our system is its ability to push automatically information towards several devices, collective devices are used for the "major" spoken language, and individual devices can be targeted for "minor" groups.

An other important feature of our system is that context sensing is based on a very simple location service. In many museums, RFIDs are already used for object referencing. Our system can be easily deployed, just by using existing tags and WLAN communications.

The research in the area of determining user location is in broad categories: the cellular communication system, the ultra sound, infrared based systems or RFID based system... However, each solution has different advantages and disadvantages.

The two positioning technologies most know in the cellular communication system is Time Difference Of Arrival (TDOA) and Angle Of Arrival (AOA). TDOA systems use the principle that the position transmitter can be estimated by the function of the difference in arrival times of signals at two or more base stations. However, a very small de-synchronization may cause a positioning error in several tens of meters. The AOA system uses simple triangulation based on the estimated angle of arrival of a signal to two or more base stations to estimate the location of the transmitter. This system requires special antenna to determine the exact angle of reception. Furthermore, because these systems are promising for outdoor environments, then their effectiveness in indoor environments is limited by the multiple reflections of the radio signal frequency (RF). This leads to an inaccurate estimate of the TDOA or AOA, and a very expensive material for a synchronization time.

The infrared based systems have been proposed in many recent applications for user's location. In the Active Badge system [11] and [12], a badge worn by a person emits a unique infrared signal. The IR fixed receivers catch this signal and relays it to the location center. The characteristic of an IR signal is to not broadcast for long distance, it is then locked in a room with walls. This will properly position the user in a room. The technique based on the IR signal proposes several disadvantages such as limited scope, the cost of installation, and sensitivity to interference in the presence of direct sunlight. Similarly, Criket [13] combines the technology of RF and ultrasound for location-aware services. The transmitter on the ceiling broadcasts the frames of radio frequency (RF). After receiving a few bits of these frames RF, the receiver switches to the communication mode ultrasound and begins to capture the ultrasonic pulses that arrive just after the frames RF a few moments. The receiver measures the time difference in receiving between the first bit of RF and ultrasonic signal and uses the maximum likelihood to estimate the distance. The disadvantage of this approach is overloading treatment on the side of receiver and the installation cost.

A positioning system on the active RFID LANDMARC [15] uses RFID tags fixed to serve as reference points. This approach requires the signal strength of each tag for readers in the detectable range. Each reader has a preset power threshold to limit the radius for detecting RFID tags. He then compares the received power level of the detected tag with a preliminary power measure to know what distance is. The advantage of LANDMARC is that power information is updated regularly and to correctly locate at a distance of 1 meter with 50% error. However, this approach should suffer an important interference of a large number of tags and readers, the movement of people within range of application and the cost.

The closest related work to our solution of indoor localization is the RADAR system [14] which uses the RF signal strength to estimate the distance between the receiver and the transmitter. During the first phase (offline stage) RSSI vectors corresponding to each location (*fingerprint*) are measured and stored in a database server as a map of RSSI. During the second phase (online stage), thanks to information from the user's signal strength RSSI, the server uses the approach of the K nearest neighbors to determine the position of the user on the map of RSSI.

Our solution does not require the deployment of specific technologies (like a specific antenna) or the use of a first phase to generate radio conditions fingerprint. We use instead a simple and effective technology of Wireless LAN and RFID to obtain a correct location of users in museum. SNR information is updated on the server side whenever the user reads an RFID tag. And finally the installation cost is low and has a small impact on server side.

6 Conclusion

In this paper, we present the design of a context-sensing service for providing pertinent information to visitors in a museum. This service has the ability to detect and identify groups of users co-located in a given area of the museum, and to provide them with unsolicited messages. Two aspects are treated by this service. First a provisioning strategy allows to target visitors according to their spoken language, collective resources are allocated to the larger group, and PDA carried by visitors are used for smaller groups. And second, visitor's context, based on visitor's localization and visitor's "spoken language", is calculated using a simple location service. The latter uses RFIDs disseminated in the museum in combination with WLAN connectivity. It does not require any off-line phase for recording radio conditions, and it just uses the similarity of radio conditions between close visitors. Considering the targeted service, our simulations show that visitor's localizations are estimated with a good degree of accuracy.

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